NOTICE OF PUBLIC MEETING TO CONSIDER THE APPROVAL OF CALIFORNIA'S 1990 SMALL OFF-ROAD ENGINE EMISSION INVENTORY

The Air Resources Board (ARB) will conduct a public meeting at the time and place noted below to consider approving the 1990 small off-road engine emission inventory.

DATE: March 26, 1998

TIME: 9:30 A.M.

PLACE: Air Resources Board
Board Hearing Room, Lower Level
2020 L Street
Sacramento, California

This item will be considered at a two-day meeting of the ARB commencing at 9:30 a.m., March 26, 1998, and continuing at 8:30 a.m., March 27, 1998, if necessary. This item may not be considered until March 27, 1998. Please consult the agenda for this meeting which will be available at least ten days before March 26, 1998, to determine the day on which this item will be considered.

INFORMATIVE DIGEST OF PROPOSED ACTION/PLAIN ENGLISH POLICY STATEMENT OVERVIEW

Proposed Actions: The ARB staff recommends the Board approve the update to the small off-road engine Emission Inventory.

Background: California's emission inventory for small off-road engines is an estimate of the amounts and types of pollutants emitted from thousands of pieces of equipment used in lawn and garden, industrial, and commercial applications. The development of the emission inventory is a multi-agency effort. The ARB compiles the final, statewide inventory.

Section 39607(b) of the California Health and Safety Code has, for may years required the ARB to inventory emissions from sources of air pollution. The ARB has published inventories and updates for over 25 years. Improvements have been made periodically to maintain and provide the most complete, accurate, and up-to-date inventory practicable.

SB 2174 (Health and Safety Code section 39607.3), passed in 1996, requires the Board to approve, at a non-regulatory public meeting, the emission inventory for criteria pollutants including emissions form mobile, stationary, area-wide, and nonanthropogenic sources. While the Board met its H&SC 39607.3 obligation by approving the statewide emissions inventory in December, 1997, staff at that time committed to return to the Board for approval of the OFFROAD inventory. Staff is therefore proposing this update to the small off-road engine portion of the new off-road inventory both to meet its H&SC 39607(b) commitment, and to fulfill its promise to the Board.

AVAILABILITY OF DOCUMENTS AND CONTACT PERSON

The ARB staff has prepared a Staff Report entitled "Public Meeting To Consider Approval Of The California Small Off-Road Engine Emission Inventory" (Staff Report), which includes a summary of the proposed action. Copies of the Staff Report may be obtained from the California Air Resources Board, Public Information Office, 2020 L Street, Sacramento, California, 95814, (916) 322-2990.

Copies of the 1990 Emission Inventory for Small Off-Road Engines can be obtained by calling ARB's Mobile Source Control Division at (626) 575-6800.

Further inquires regarding this matter should be directed to Mark Carlock, Chief, Motor Vehicle Analysis Branch, 9528 Telstar Avenue, El Monte California 91731, (626) 575-6608.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter verbally or in writing. To be considered by the Board, written submissions must be addressed to, and received by the Clerk of the Board, the Air Resources Board, P.O. Box 2815, Sacramento California 95812, no later than 12:00 noon, March 25, 1998, or received by the Clerk of the Board at the meeting.

The Board requests, but does not require, that 20 copies of any written statement be submitted and that all written statements be filed at least ten days prior to the meeting. The ARB encourages members of the public to bring any suggestions for modification of the proposed action to the attention of staff in advance of the meeting.

CALIFORNIA AIR RESOURCES BOARD

Michael P. Kenny
Executive Officer

Date:

California Environmental Protection Agency

AIR RESOURCES BOARD

PUBLIC MEETING TO CONSIDER APPROVAL OF THE CALIFORNIA SMALL OFF-ROAD ENGINE EMISSIONS INVENTORY

Air Resources Board
Mobile Source Control Division
Motor Vehicle Analysis Branch

March 1998

Table of Contents

LIST OF FIGURES

Acronyms Used in Staff Report

ARB	Air Resources Board
BAH	Booz, Allen and Hamilton
BER	Basic Emission Rate
Board	Air Resources Board
cc	Cubic Centimeter
CNG	Compressed Natural Gas
CO	Carbon Monoxide
Comm	Commercial
EMA	Engine Manufacturers Association
g/bhp-hr	Grams per Brake-Horsepower-Hour
HC	Hydrocarbons
HH	Handheld
H&SC	Health and Safety Code
HP	Horsepower
LPG	Liquid Petroleum Gas
NH	Non-Handheld
NOx	Oxides of Nitrogen
PM	Particulate Matter
PPEMA	Portable Power Equipment Manufacturers Association
PSR	Power Systems Research
Res	Residential
SB	Senate Bill
U.S. EPA	United States Environmental Protection Agency

PUBLIC MEETING TO CONSIDER APPROVAL OF THE CALIFORNIA SMALL OFF-ROAD ENGINE EMISSIONS INVENTORY

RECOMMENDATION

The staff recommends the Air Resources Board (ARB or Board) approve the draft, statewide, annual average, 1990 Emission Inventory for Small Off-Road Engines (less than 25 horsepower) as presented in Table 1. This is the latest year for which complete data are available because key reference surveys were performed for 1990. A wealth of additional information on industry trends was provided through the public comment process which will ensure that projections of this inventory to 1998, 2000, 2005 and 2010 are accurate.

The staff will use the approved inventory to produce other types of inventories, such as inventories for past and future years, and inventories used for planning and air quality modeling purposes. Senate Bill 2174 requires the Board to review the emission inventory at a minimum of every three years. Staff intends to follow this three year schedule, however, staff may seek Board review of portions of the inventory sooner than three years if significant changes with major policy consequences are suggested by new information.

TABLE 1
1990 SMALL OFF-ROAD EMISSIONS INVENTORY
(Statewide - Tons per Day)

Fuel	Type	HC	CO	NOx	PM
Gasoline	**2 Stroke**	65.29	196.57	0.26	1.57
Gasoline	**4 Stroke**	50.44	1163.34	8.33	1.06
CNG	**4 Stroke**	0.06	1.86	0.02	0.00
Diesel	**N/A**	3.06	8.83	13.90	1.48
Total		**118.85**	**1370.60**	**22.51**	**4.11**

CHAPTER I. INTRODUCTION

California's small off-road engine emission inventory is an estimate of the amount and types of pollutants emitted from thousands of pieces of equipment with a rating of less than 25 horsepower, which are used in off-road applications such as lawn and garden, construction and agriculture.

The Air Resources Board and local districts use emissions inventories to describe and compare the contribution of various sources to air pollution, to establish priorities for developing methods of emission control, to prepare air quality plans, develop rules, and assess the progress of the State's air pollution control program.

Statutory Requirement

The California Health and Safety Code (H&SC) section 39607(b) for many years has required the Air Resources Board to inventory emissions from sources of air pollution. Staff has periodically updated and published statewide emissions inventories.

Senate Bill 2174 (H&SC section 39607.3), signed by Governor Wilson on September 21, 1996, requires the Board to approve at a public meeting, the emission inventory for criteria pollutants including emissions from mobile, stationary, area-wide, and non-anthropogenic sources. The Board's initial approval was required no later than January 1, 1998 and subsequent updates to the inventory are required at least every three years.

The Board approved the emissions inventory in December of 1997. However, because the new computer model for the estimation of the off-road emissions inventory called "**OFFROAD**" was not complete, the Board approved the existing inventory for off-road mobile sources. At that time, staff made a commitment to bring the revised estimates before the Board prior to the end of 1998. The staff is seeking Board approval of the revisions to the small off-road emissions inventory as the first step in this process. Staff is therefore proposing this update both to meet its H&SC 39607(b) commitment, and to fulfill its promise to the Board.

CHAPTER II. PUBLIC PROCESS AND PUBLIC AVAILABILITY

The revisions to the small off-road emissions inventory were performed through a public process in which input was solicited from various agencies, air quality management districts, engine manufacturers, and technical consultants. ARB staff is ultimately responsible for the compilation of the final statewide emissions inventory, which is maintained in an electronic database.

The regulated community and interested stakeholders play a critical role in the review and development of the emissions inventory during the planning and regulatory process. They also participate actively in inventory workshops and in development of data and methodologies that improve the inventory. The ARB staff met often with representatives of industry associations to better understand the emission processes and to use their technical expertise and data to improve the inventory.

Two public workshops were conducted in early April of 1997, one in Sacramento and the other in EL Monte, in order to discuss the implications of SB 2174 on inventory development, and provide detailed descriptions of the data and methodologies used in the new OFFROAD model. The OFFROAD model is used by staff to estimate the emissions inventory for small off-road engines (and all other off-road mobile sources).
These workshops were well attended by representatives of both government and industry. In these workshops, staff presented the program structure, features, and data sources used in the OFFROAD model. Staff also released a report entitled "Documentation of Input

Factors for the new Off-Road Mobile Source Emissions Inventory Model" for public comment. In early May the same report was mailed to other parties who expressed an interest but could not attend the workshops. Since that time, staff has responded to many of the comments related to data sources used in the OFFROAD model and the structure of the model itself.

In December of 1997, staff held a third workshop at the Air Resources Board's laboratory in El Monte to discuss the data sources and program structure of the OFFROAD model as they specifically relate to the exhaust and refueling emissions inventory of small off-road engines. Prior to this workshop, staff provided electronic copies of all databases and the source code of the OFFROAD model to those technical consultants retained by the Engine Manufacturers' Association (EMA) and Portable Power Equipment Manufacturers Association (PPEMA). At the workshop, EMA and PPEMA provided comments through their technical consultants and staff responded to their suggestions by modifying the inventory where deemed appropriate.

Since December, an ongoing dialogue has been maintained between ARB inventory staff, EMA and PPEMA through a series of face to face meetings, telephone conferences and through the exchange of information via electronic mail.

CHAPTER III. EMISSION INVENTORY MODEL STRUCTURE

Introduction

The 1990 Emission Inventory for small off-road engines includes total emissions for the entire state, subtotals for each of the 16 air basins and subtotals for each county or portion of a county in each air basin. The data in Table 1 summarize the statewide inventory of reactive organic gases (ROG), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter 10 microns in diameter and smaller (PM10). Collectively, these pollutants are known as "criteria" pollutants.

From the data used to produce the basic annual average emission inventory, staff prepares other types of inventory products. Some examples are: future year forecasts used to judge attainment prospects, trends to show historical patterns, seasonal inventories for planning purposes, day-specific inventories for use in ambient air quality models, and updated, prior-year inventories used in trend and progress assessments. These other estimates are based on the annual average emission inventory data and additional data needed to produce the specific estimate. Some of the other data sets required include temporal data, growth and control assumptions, spatial data, and historical assumptions.

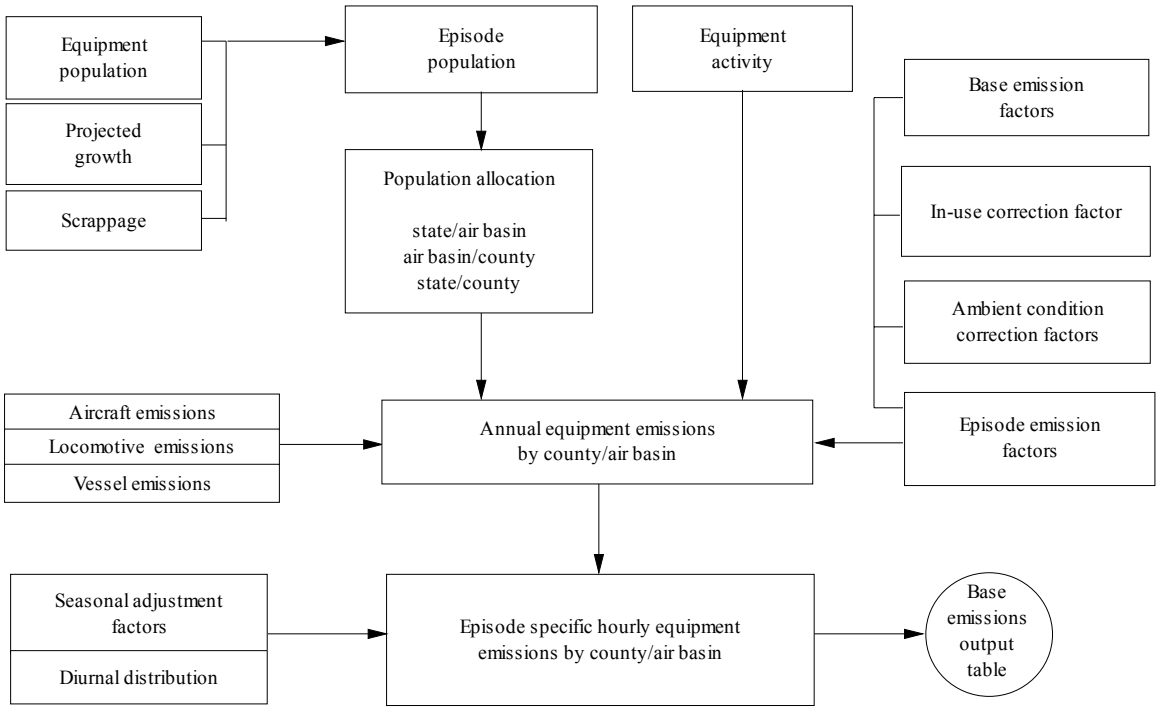
The inventory category "Other Mobile Sources" is not limited to small off-road engines. Other Mobile Sources include 14 categories of emissions sources such as: off-road recreational vehicles, commercial/industrial mobile equipment, farm and construction

equipment, aircraft, trains, ships, commercial boats, and recreational boats. Estimating the emissions from these categories is primarily the responsibility of the ARB, but some categories are estimated by the districts or the United States Environmental Protection Agency (U.S. EPA), such as emissions from aircraft and ships. In this Section, staff presents the structure and algorithms used to revise and improve the emission inventory of small off-road engines using the OFFROAD model.

B. Program Structure

The primary emphasis in designing OFFROAD was to provide an overall structure to incorporate the various aspects of off-road source emissions modeling, such as the effects of various adopted and proposed regulations, technology types, and seasonal conditions on emissions. This overall structure is illustrated in Figure 1. Fundamentally, the population, activity, and emission factors are still combined to yield the annual equipment emissions by county, air basin, or state. However, spatial and temporal features have been incorporated, making the new model more accurate in its depiction of emissions.

FIGURE 1
Flowchart of Overall Program Structure of OFFROAD



OFFROAD consists of four main modules: population, activity, emissions, and control factor. The 1990 base year equipment population is adjusted for growth and scrappage, producing model-year specific population distributions for specified calendar years from 1970 through 2020. The statewide population is allocated to each geographic region.

The base emission factors are corrected for in-use and ambient conditions. The annual equipment emissions are adjusted for seasonal and diurnal factors producing the base emissions output.

The output tables of OFFROAD have a standard layout that displays activity information and emission data. The activity table includes information regarding the population, use hours per day, starts per day, and gallons of fuel consumed per day. The emission estimates are reported for three processes: exhaust, evaporative, and starts. While the output tables aggregate the information by equipment category for the state, the model can also produce more distinct information such as emission estimates of certain equipment type within a county.

C. Methodology

OFFROAD generates an emission inventory for six pollutants by equipment type, accounting for age and for a given scenario year. The basic equation for OFFROAD is:

$$P_{i,y} = \sum_{i} Pop_{i,v} * EF_{i,v} * Hrs_{i,v}$$

where

P = pollutant (HC, CO, NO_X, PM, CO_2, SO_2)
Pop = equipment population
EF = emission factor
Hrs = annual average use hours
y = scenario year (1970-2020)
I = equipment type
v = vintage (age of equipment)

1) Population Module

This module contains growth factors and scrappage curves that are used to derive an equipment-specific model year population distribution for specified calendar years from 1970 through 2020. The statewide equipment population was obtained through various industry and government agency sources and was divided at the air basin and county level using activity indicators that reflect their usage in those areas.

a) Categories and Equipment Types

There are 95 equipment types aggregated into 14 categories as listed in Table 2. In general, the 14 categories include all equipment types used for a similar purpose or industry. According to the Federal Clean Air Act, emissions from certain equipment

types can only be regulated by the U.S. EPA and are, therefore, preempted from State regulation. The equipment types are further divided by fuel, engine type, horsepower group, and preempted or non-preempted status to better characterize emissions, adopted and proposed control strategies, and use. Table 3 shows the fuel type, engine type, and horsepower groups included in the model.

Tables 2 and 3 provide the category and horsepower information for all off-road sources. Those portions of the table shown in bold letters are specific to small off-road engines.

b) Growth and Scrappage

The growth factors are based on socioeconomic indicators such as housing units and manufacturing employment by category, by county, and with respect to the 1990 base year sales. Scrappage is a static function of equipment age and use which varies by engine type and horsepower group. For all equipment types, except lawn and garden equipment and recreational vehicles, the equipment useful life equals the life of the engine represented in years. The number of model years accounted for are twice the equipment useful life. The maximum useful life modeled is 16 years which translates to 32 model years in a given calendar year. Therefore, the baseline model year distribution is also dependent on the useful life of the equipment. Due to the lack of any other information, the 1990 model year distribution is used for the 1970-1989 calendar years.

TABLE 2
List of Equipment by Category

a. Lawn and Garden Equipment
1. **Trimmers/Edgers/Brush cutters**
2. **Lawn mowers**
3. **Leaf blowers/vacuums**
4. **Rear engine riding mowers**
5. **Front mowers**
6. **Chainsaws < 5 HP**
7. **Shredders < 5 HP**
8. **Tillers < 5 HP**
9. **Lawn and garden tractors**
10. **Wood splitters**
11. **Snow blowers**
12. **Chippers/Stump grinders**
13. **Commercial turf equipment**
14. **Other lawn and garden equipment**

b. Light Commercial Equipment (0-50 HP)
1. **Generator sets**
2. **Pumps**
3. **Air compressors**
4. **Gasoline compressors**
5. **Welding machines**
6. **Pressure washers**

c. Recreational Equipment
1. All Terrain Vehicles (3 & 4 wheel vehicles)
2. Off-road motorcycles
3. Golf carts
4. Specialty vehicles/carts
5. Snowmobiles

d. Industrial Equipment
1. Aerial lifts
2. Forklifts
3. Sweepers
4. Other general industrial equipment
   - Abrasive blasting equipment
   - Industrial blowers/vacuums
   - Marine/industrial winches and hoists
   - Multipurpose tool carriers
   - Other misc. industrial equipment (catch all)

* (Industrial continues next column)

d. Industrial Equipment (cont)
5. Other material handling equipment
   - Conveyors
   - Other misc. material handling (catch all)
   - Industrial tractors

e. Construction and Mining Equipment
1. Asphalt pavers
2. Tampers/Rammers
3. Plate compactors
4. Concrete pavers
5. Rollers
6. Scrapers
7. Paving equipment
8. Surfacing equipment
9. Signal boards
10. Trenchers
11. Bore/Drill rigs
12. Excavators
13. Concrete/Industrial saws
14. Cement and Mortar mixers
15. Cranes
16. Graders
17. Off-Highway trucks
18. Crushers/Processing equipment
19. Rough terrain forklifts
20. Rubber tire loaders
21. Rubber tire dozers
22. Tractor/Loaders/Backhoes
23. Crawler tractors
24. Skid steer loaders
25. Off-Highway tractors
26. Dumpers/Tenders
27. Other construction equipment

f. Agricultural Equipment
1. **2-Wheel tractors**
2. **Agricultural tractors**
3. **Agricultural mowers**
4. **Combines**
5. **Sprayers**
6. **Balers**
7. **Tillers > 5 HP**
8. **Swathers**
9. **Hydro power units**
10. **Other agriculture equipment**

TABLE 2 (continued)

g. Logging Equipment
1. **Chain saws > 5 HP**
2. **Shredders > 5 HP**
3. **Log skidders**
4. **Fellers/Bunchers**

h. Airport Ground Support Equipment
1. **Airplane tow tractors**
2. **Baggage/Cargo tow tractors**
3. **Ground power units**
4. **Start units**
5. **Deicing units**
6. **Load lifting and handling**
7. **Service utility carts**
8. **Pressure washers**

i. Pleasure Craft
1. Inboard powerboats <250 HP
2. Outboard powerboats
3. Sterndrive powerboats
4. Inboard sail-auxiliary
5. Outboard sail-auxiliary

j. Commercial and Government Vessels
1. Commercial inboard boats >250 HP
2. Commercial in/outboard boats
3. Commercial tug boats
4. US Coasts Guard boats
5. Seagoing vessels
   - Motorships
   - Steamships

k. Transport Refrigeration Units
1. **Small units < 25 HP**
2. **Large units > 25 HP**

l. Locomotive and Rail Operations
1. Line haul operations
2. Yard operations

m. Aircraft: Commercial, Military, and General Aviation
1. Landing and Takeoff Operations (LTO)

n. Agricultural Aircraft
1. Aircraft operations below 3,000 ft.

TABLE 3

Various Fuels, Engine Types, and Horsepower Groups Used in the OFFROAD Model

Fuel	Engine Type	Horsepower Groups
Gasoline	2-stroke	0-2, 2-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Gasoline and CNG/LPG	4-stroke	0-5, 5-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Diesel		0-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750, 750+

2) Activity Module

This module contains information such as annual average use hours, load factor, brake-specific fuel consumption, and starts per year for each equipment type by fuel, engine type, and horsepower group. The activity information reflects seasonal and temporal conditions, as described below.

a) Seasonal and Temporal Parameters

The equipment types from diverse industries such as agriculture, construction, and recreation, are included in the OFFROAD model, and their usage patterns are not identical. These seasonal and temporal influences are resolved by monthly, weekly, and daily use patterns for each type of equipment.

Most of the categories (construction, industrial, light commercial, and airport ground service equipment) have uniform activity throughout the year. Recreational vehicles, lawn and garden, and farm equipment display various seasonal use patterns. Equipment types within a category have the same monthly use pattern except for snowmobiles, snow blowers, chain saws (<=5 HP), and tillers. Although most lawn and garden equipment undergo peak use during the summer, chain saw and tiller use peaks during the winter and spring, respectively. In order to be consistent with the seasonal attributes of reformulated fuels, summertime is defined as May through October while wintertime is considered November through April.

There are three types of weekly use patterns: average, weekday, and weekend. The average, or no peak, use pattern is exhibited by airport ground service and transport refrigeration units. Construction, industrial, and farm display mostly weekday, some Saturday, and less Sunday activity. Instances where weekend use is greater than weekday use would be recreational vehicles and lawn and garden equipment.

The daily activity is distributed into eight 3-hour periods (e.g., 3:00, 6:00, 9:00, etc.). The bulk of the activity occurs between 9 a.m. and 6 p.m., which is the daytime use pattern. Airport ground service equipment is utilized whenever the airport is open, and include servicing of cargo and regular maintenance. Therefore, the use pattern is primarily during business hours with some off-peak activity. In contrast, transport refrigeration units are operated more evenly throughout the entire day because perishables are shipped at night for morning delivery.

3) Emissions Module

This module contains emission rate equations (emission factors) by model year for HC, CO, NO_X, PM, CO_2, and SO_X emissions. HC emissions are modeled for three types of processes: exhaust, evaporative, and start. The emission factors are a function of new engine emissions expressed in gram per brake horsepower hour (g/bhp-hr), and deterioration rates, expressed as a rate of increase in emissions per useful life.

Since several equipment types use the same types of engines, the exhaust emission factors are engine-specific. Equipment-specific emission rates are obtained by adjusting the appropriate engine emission rate according to how the equipment is used (duty cycle). The model-year-specific emission rates also reflect the effect of reformulated fuels and stringent emission standards adopted by the Board. Due to the lack of emission data, the deterioration rates are generally based on on-road emissions data[1], with the exception of small off-road engines, which were obtained from emission test results provided by engine manufacturers.

Evaporative emission factors account for refueling, diurnal, hot soak, running, and resting losses. Evaporative emissions are equipment-specific and dependent on fuel systems. Evaporative emissions are only necessary for gasoline equipment since diesel fuel has low volatility and LPG systems are pressure sealed. Due to the lack of data, placeholders are used for hot soak, running, and resting losses. This module also contains correction factors for temperature, reformulated fuels, and volatility. Although no data are currently available, the model is equipped to provide emissions due to start up procedures.

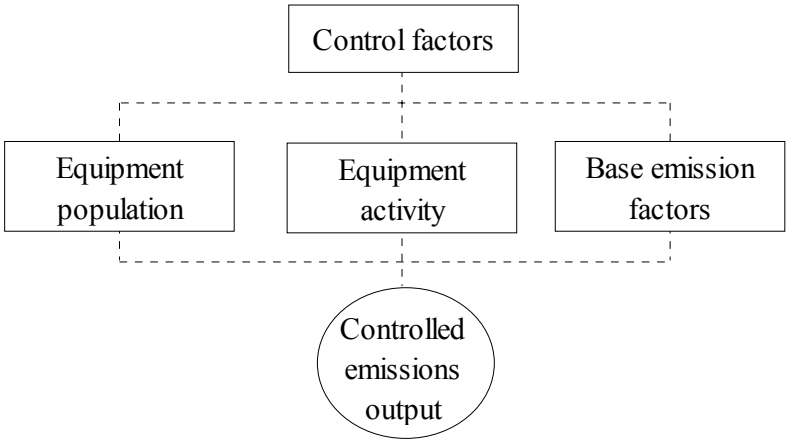
4) Control Factor Module

OFFROAD can also account for regulatory control scenarios as illustrated in Figure 3. The control factor file is a multiplicative adjustment indicated by polluting source, pollutant, beginning year, and ending year. Control factors can be applied to emission rates, activity, and populations. An example of a population control strategy would be to retrofit a particular model year group with an emission control device. Limiting use during peak hours would be an example of an activity control scenario. When this feature is employed, the output consists of both baseline and controlled scenarios.

---

[1] **California Air Resources Board, "Technical Support Document, Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles," July 1990.**

FIGURE 2
Controlled Emissions Output



CHAPTER IV. REVISIONS TO THE BASELINE INVENTORY

A. Introduction

Previous versions of the small off-road inventory relied heavily upon emission and activity data compiled by Booz, Allen and Hamilton (BAH) in their October1990 Report to the Air Resources Board entitled "Report on Utility Engine Emissions in the State of California". In the construct of the OFFROAD model, more recent or more accurate information from Power Systems Research (PSR), U.S. EPA and manufacturers submissions were utilized where appropriate. As a result, the inventory for small off-road engines presented by ARB staff in their December 1997 workshop was substantially higher than previously estimated. Table 4 contrasts the previous small off-road emissions inventory with the December estimates.

TABLE 4
1990 Statewide Inventory (Tons per Day)

Fuel	Type	HC	CO	NOx	PM
BAH INVENTORY					
Gasoline	**2 Stroke**	53	164	0.22	1.14
Gasoline	**4 Stroke**	17	331	1.77	0.28
Diesel	**N/A**	0.6		2.11	0.32
Total		**70.6**	**495**	**4.10**	**1.74**
OFFROAD INVENTORY (12/97)*					
Gasoline	**2 Stroke**	85.62	260.90	0.32	1.44
Gasoline	**4 Stroke**	50.44	1163.40	8.33	1.06
CNG	**4 Stroke**	0.06	1.80	0.02	0.00
Diesel	**N/A**	3.06	8.80	13.90	1.48
Total		**139.18**	**1434.90**	**22.56**	**3.97**

***The 12/97 version of the model is not being proposed for adoption.**

The resultant increase in the inventory is attributable to the addition or reclassification of equipment types, the addition of addition fuel categories, modifications to the average horsepower, load factors, population, activity/usage and base emission rates. Table 5 presents the sources of information used to update the small off-road engine inventory.

TABLE 5
SOURCES OF INFORMATION USED IN THE OFFROAD MODEL

	BAH	OFFROAD
General	Equipment level, engine type and Residential/Commercial specific data	Equipment level, engine type and HP category specific data
Equipment	From: • Lawn & Garden • General Utility	From: • Construction • Light Industrial • Lawn & Garden • Farming • Light Commercial • Logging • Airport Transportation • Refrigeration
Engine Types	G2, G4	G2, G4, C4, D
Average HP	Lawn & Garden: • Equipment, G2/G4 specific • Equipment, Res./Comm. Specific General Utility: • G2/G4 or Res./Comm. Specific	All: • Source: PSR database • Equipment, engine and HP category specific.
Load	Lawn & Garden: • Equipment specific General Utility: • Category specific	Equipment specific • Lawn & Garden: from BAH • Other: from PSR
Population	Lawn & Garden: • Equip and G2/G4 specific or • Equip and Res./Comm. Specific General Utility: • G2/G4 specific	Lawn & Garden: • BAH G2/G4 specific population values broken out to HP categories General Utility: • Equipment, G2/G4 and HP specific data from PSR
Activity/Usage	Lawn & Garden: • Equip and G2/G4 specific or • Equip and Res./Comm. Specific General Utility: • G2/G4 specific	Lawn & Garden: • BAH Res./Comm. weighted composite Other: • Equipment specific by G2/G4/D/C4
Base Emission Rates (BERs)	All: • Equipment, Res./ Comm. Specific • No deterioration factor	All by Engine Type: • G2: Activity weighted BAH BERs by HH/NH, HP groups • G4: EPA/EEA BERs; HP specific • C4: BERs with deterioration factors • D: BERs with no DFs

B. Differences Between BAH and OFFROAD

In comparison to the model based on BAH data, the OFFROAD model contains a more comprehensive list of equipment from a wider range of categories. The OFFROAD model adds an inventory estimate for engines powered by diesel fuel, compressed natural gas (CNG) and liquid petroleum gas (LPG) which were not previous accounted for. Over 30 tons per day of HC+NOx is attributable to equipment included in the OFFROAD model which was previously unaccounted for.

In evaluating the effect of single parameter contributions to the overall ton per day differences in the OFFROAD and BAH inventories, increases or decreases in the inventory correspond directly to changes in the assumed population, activity, average horsepower, load or useful life. Evaluating the combined contributions of more than one parameter, however, is not as obvious. Therefore, a detailed stepwise analysis of the differences between the small off-road engine emissions inventory as calculated using the BAH data and the OFFROAD model is presented in Appendix A of this report.

C. Summary of Changes in Response to Comments

1. Classification of Equipment by Handheld and Non-handheld

The small off-road engine regulation draws a distinction between handheld equipment (e.g. chain saws) and non-handheld equipment (e.g., lawn mowers). Handheld equipment utilizes smaller, lighter engines (between 0 and 60 cc) and non-handheld equipment tend to utilize engines greater than 60 cc. EMA suggested that the OFFROAD model classify all small off-road engines as either handheld and non-handheld, to more accurately reflect the application of the ARB's adopted Tier I and proposed new Tier II regulations. Appendix B of this report provides a complete listing of handheld and non-handheld engines.

2. Preemption of Chainsaws Between 2hp and 15hp

In agreement with engine manufacturers and USEPA, ARB staff has developed a list of preempted and non-preempted equipment in the small off-road engine inventory. Per this agreement, chainsaws utilizing engines of 45 cc and above are preempted. Based on data provided by PPEMA, 35 percent of chainsaws in the 2-15 hp group were reclassified as being preempted from California regulation.

3. Uncontrolled Basic Emission Rates for Handheld-2 Stroke Gasoline Engines

Based upon comments provided by PPEMA, staff re-weighted the equipment specific uncontrolled basic emission rates of 2 stroke gasoline engines using equipment specific activity instead of equipment specific population. The revised emission rates for 2 stroke gasoline engines are shown in Appendix B.

4. Revision to Population Estimates of Edgers/Trimmers

PPEMA raised concerns regarding the baseline population estimates used in the OFFROAD model for chainsaws, trimmers and backpack blowers. Through the exchange of information between ARB and PPEMA staff, the assumed populations for chainsaws and blowers used in the OFFROAD model were deemed appropriate. Edgers and trimmers, however, appeared to be 40 percent higher in the OFFROAD model compared to industry production data. As a result, the baseline population estimate for this category of engine was reduced in the model.

5. Summary of Other Comments Considered by the ARB Staff

Both EMA and PPEMA also commented on the fact that in OFFROAD model does provide separate emissions estimates according to residential and commercial use. Staff explained that in OFFROAD model, residential and commercial lawn and garden equipment specific population and activity are weighted together in that no regulatory strategy specific to residential or commercial equipment has been proposed. Although a separate reporting of residential and commercial equipment inventories is not possible using this approach, the resulting inventories are the same.

Taken in their entirety, the modifications to the baseline inventory estimates resulted in a 20 ton per day decrease in HC, a 64 ton per day decrease in CO in the estimated inventory for small off-road engines in 1990 compared to the December 1997 estimates. Negligible changes in the NOx and PM inventory also resulted from these changes (See Table 6).

TABLE 6
Changes In the Inventory
In Response to Comments
(1990 Statewide – Tons per Day)

OFFROAD INVENTORY (12/97)					
Fuel	**Type**	**HC**	**CO**	**NOx**	**PM**
Gasoline	**2 Stroke**	85.62	260.90	0.32	1.44
Gasoline	**4 Stroke**	50.44	1163.40	8.33	1.06
CNG	**4 Stroke**	0.06	1.80	0.02	0.00
Diesel	**N/A**	3.06	8.80	13.90	1.48
Total		**139.18**	**1434.90**	**22.56**	**3.97**

OFFROAD INVENTORY (3/98)					
Gasoline	**2 Stroke**	65.29	196.57	0.23	1.57
Gasoline	**4 Stroke**	50.44	1163.34	8.33	1.06
CNG	**4 Stroke**	0.06	1.86	0.02	0.00
Diesel	**N/A**	3.06	8.83	13.90	1.48
Total		**118.85**	**1370.60**	**22.48**	**4.11**

CHAPTER V. GROWTH AND CONTROL

A. Growth Factors in the OFFROAD Model

The growth factors utilized in the OFFROAD model are a result of a study performed by Cal State Fullerton's Institute for Economic and Environmental Studies. The results of this study are outlined in a report prepared for the Air Resources Board entitled "A Study to Develop Projected Activity for "Non-Road Mobile" Categories in California, 1970-2020". In this report, certain economic indicators are used to project the growth in population and usage of small off-road engines in various applications. In general, the population of small off-road equipment is expected to increase by approximately 34% between 1990 and the year 2010.

B. Control

In December of 1990, the Air Resources Board adopted two levels of emission standards for small off-road engines. The first phase of standards (Tier 1) was implemented in 1995 and Tier 2 standards are scheduled for implementation in 1999. In order to reflect the change in the inventory due to the implementation of these emission reduction standards, staff utilized emissions data supplied to the ARB as required under quality audit guidelines. These data were used to derive Tier 1 emission rates. The deterioration rates for 4 stroke Tier 1 engines were derived from data supplied by engine manufacturers. Since engines meeting Tier 2 standards are not yet available, engineering judgment was used to estimate the effect of the more stringent standards. The zero hour emission rates and deterioration rates used for Tier 1 and Tier 2 engines are listed in Appendix B of this report.

C. Comments Received Regarding Growth

Both EMA and PPEMA commented on the growth factors utilized by OFFROAD to project the 1990 equipment population to 2010. After considering several alternative sources of data including information provided by PPEMA, it was concluded that the growth factor currently utilized in the OFFROAD model are adequate.

The projected statewide small off-road engine emissions inventory for the year 2010 is listed in the table below.

TABLE 7
SMALL OFF-ROAD ENGINE INVENTORY
FOR 2010
(Statewide-Tons per Day)

Fuel	Type	HC	CO	NOx	PM
Gasoline	**2 Stroke**	35.00	72.23	0.27	0.93
Gasoline	**4 Stroke**	34.09	604.17	5.33	1.36
CNG	**4 Stroke**	0.07	2.38	0.02	0.00
Diesel	**N/A**	3.81	5.16	9.54	1.00
Total		**72.97**	**683.94**	**15.16**	**3.29**

CHAPTER VI. SUMMARY AND CONCLUSIONS

This Board item marks the first in a series of presentations to the Board seeking approval of the off-road inventory in its entirety. The finalization of the small off-road engine inventory is tied to pending regulatory action regarding this portion of the fleet with the understanding that estimates of effectiveness and cost depend heavily upon the accuracy of the inventory estimates.

The small off-road inventory estimates presented in this report were subjected to extensive public review and technical scrutiny. Although this process resulted in the delayed release of the estimates, all issues regarding the accuracy of the inventory were addressed. It is believed that this is the most accurate estimate of emissions from this class of engines available.

Staff recommends the approval of the statewide, 1990 emissions inventory for small off-road engines as well as the projections to future years.

Appendix A

Stepwise Analysis of Changes in the Inventory

BAH and OFFROAD Inventory Comparison - Stepwise Analysis:

The estimation of the inventory for small off-road engines using the Booz, Allen, Hamilton (BAH) methodology or the OFFROAD model will yield different results for many reasons. At a fundamental level, the data used in BAH and OFFROAD are inherently different in their level of detail and how each is organized. BAH data is developed on the equipment specific level and further subdivided into residential and commercial classifications. Although the OFFROAD model also utilizes equipment specific data, no distinction is made between residential and commercial classifications. Instead, the OFFROAD model organizes the emissions and activity data into horsepower (HP) groupings. The base emission rates (BERs) used in the BAH methodology assumed no deterioration rate (DR), while OFFROAD uses HP specific deterioration factors. OFFROAD also adds an accounting for small off-road engines powered by diesel, liquid petroleum gas (LPG), and compressed natural gas (CNG) which were absent from the BAH methodology. Table 1 shows results of the stepwise analysis which compares BAH and OFFROAD inventory. Details of the stepwise analysis are described in the following paragraphs.

In order to perform a stepwise analysis quantifying the differences between the BAH inventory and the OFFROAD inventory, it is necessary to weight together some categories of engines in order to bring place the BAH and OFFROAD estimates at a common level of detail.

In particular, this requires the compositing of BAH's residential and commercial, gas 2 Stroke (G2) and gas 4 stroke (G4) specific data to the equipment level for each G2/G4 engine type. Using the following formula, the residential and commercial specific life, average HP, load and activity parameters were population weighted to arrive at an equipment level composite value for each parameter.

Equation 1: $$\mathbf{X_{Equip} = Pct_{Res} * X_{Res} + Pct_{Comm} * X_{Comm}}$$

Where:

X_{Equip} = Equipment level composite value for a parameter

Pct_{Res} = Residential percentage;
Residential population/Total population for an equipment type

X_{Res} = Residential value for a parameter

Pct_{Comm} = Commercial percentage;
Commercial population/Total population for an equipment type

X_{Comm} = Commercial value for a parameter

Applying Equation 1 above, the resulting equipment level, G2/G4 specific parameters should match those in the BAH report for all estimates with the exception of activity (hr/yr). Reasoning that the residential/commercial activity reported in these tables are themselves averages, the composite data provided in the report were used for activity.

The composite BAH BERs for G2s were derived from residential/commercial specific BERs in the following way.

For each equipment type, compute the residential and commercial specific activity weighting using the respective residential/commercial parameters in the following formula.

Equation 2:

$$\textbf{Act Wt}_{\textbf{Res/Comm}} = \textbf{Pop}_{\textbf{Res/Comm}} * \textbf{AvHP}_{\textbf{Res/Comm}} * \textbf{Load}_{\textbf{Res/Comm}} * \textbf{Activity}_{\textbf{Res/Comm}}$$

Where:
$\text{Act Wt}_{\text{Res/Comm}}$ = Activity weighting in (hp*hr/yr)
$\text{Pop}_{\text{Res/Comm}}$ = Number of units
$\text{AvHP}_{\text{Res/Comm}}$ = Average horsepower (hp)
$\text{Load}_{\text{Res/Comm}}$ = Average load factor
$\text{Activity}_{\text{Res/Comm}}$ = Usage in (hrs/yr)

The residential and commercial BERs were weighted by their respective residential/ commercial activity weighting to arrive at the total annual emissions in (g/yr) from each equipment type.

Equation 3: $\textbf{Ann ER}_{\textbf{Res/Comm}} = \textbf{Act Wt}_{\textbf{Res/Comm}} * \textbf{BER}_{\textbf{Res/Comm}}$

Where:
$\text{Ann ER}_{\text{Res/Comm}}$ = Annual Emission rate in (g/yr)
$\text{Act Wt}_{\text{Res/Comm}}$ = Activity weighting in (hp*hr/yr)
$\text{BER}_{\text{Res/Comm}}$ = Base Emission Rate in (g/(hp*hr))

The total annual residential and commercial emissions were divided by the total residential and commercial activity to derive an activity weighted composite BER for each equipment type using Equation 4.

Equation 4:

$$\textbf{Act Wtd BER}_{\textbf{Equip}} = (\textbf{Ann ER}_{\textbf{Res}} + \textbf{Ann ER}_{\textbf{Comm}})/(\textbf{ActWt}_{\textbf{Res}} + \textbf{ActWt}_{\textbf{Comm}})$$

Where:
$\text{Act Wtd BER}_{\text{Equip}}$ = Activity weighted BER for an equipment
$\text{Ann ER}_{\text{Res}}$ = Resident equipment's annual emission rate in (g/yr)
$\text{Ann ER}_{\text{Comm}}$ = Commercial equipment's annual emission rate in (g/yr)
$\text{ActWt}_{\text{Res}}$ = Residential equipment's activity weighting (hp*hr/yr)
$\text{Pop}_{\text{Res}} * \text{AvHP}_{\text{Res}} * \text{Load}_{\text{Res}} * \text{Activity}_{\text{Res}}$
$\text{ActWt}_{\text{Comm}}$ = Commercial activity weighting (hp*hr/yr)
$\text{Pop}_{\text{Comm}} * \text{AvHP}_{\text{Comm}} * \text{Load}_{\text{Comm}} * \text{Activity}_{\text{Comm}}$

In a similar way, OFFROAD HP specific population, life, average HP, load and activity parameters were composited to the equipment and engine type specific level for each equipment type.

Equation 5: $X_{Equip} = \sum_{hp\ grp} Pct_{hp\ grp} * X_{hp\ grp}$

Where:
X_{Equip} = Equipment level composite for parameter X
$Pct_{hp\ grp}$ = Percentage total equipment in a HP group
$X_{hp\ grp}$ = HP specific parameter (population, life, average HP, load or activity)

Each OFFROAD equipment type was cross referenced to a BAH equipment type and classified as Lawn and Garden (BAH L&G) category, General Utility (GenUtil) or an equipment type not accounted for in BAH (Not in BAH). A ton per day (TPD) emission estimate for hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM) was calculated for each equipment type under the three aforementioned categories. The previously developed activity weighted BERs and populations weighted average HP, load and activity were used in the following formula to arrive at a TPD estimate for each equipment type within each engine type.

Equation 6:

$$TPD_{Equip} = Pop_{Equip} * Avg\ HP_{Equip} * Load_{Equip} * Activity_{Equip} * Act\ Wtd\ BER_{Equip} * CnvFac$$

Where:
TPD_{Equip} = Ton per day emissions of a pollutant for an equipment
Pop_{Equip} = Number of units per equipment
$Avg\ HP_{Equip}$ = Equipment level average horsepower (hp)
$Load_{Equip}$ = Equipment level average load factor
$Activity_{Equip}$ = Equipment level usage in (hrs/yr)
$Act\ Wtd\ BER_{Equip}$ = Equipment level BER for a pollutant in (g/(hp*hr))
CnvFac = Conversion Factor from (g/yr) to (tons/day)

The above equipment level tons per day estimates reproduce the inventory analysis performed by BAH. As in BAH, the BERs in this analysis are specific to an equipment type, and does not assume any deterioration throughout the life of the equipment. The TPD emission estimate for each equipment type were calculated and subtotaled to derive a TPD estimate of all equipment classified as BAH L&G, GenUtil, and Not in BAH.

To analyze the effects of parameter changes and differences from BAH to OFFROAD, BAH's population, activity, load and average HP estimates were successively changed to OFFROAD estimates of each parameter, for each equipment type. This analysis was performed in two ways: 1) Individual parameter analysis where one parameter was changed at a time, leaving all others constant, 2) Cumulative analysis where BAH parameters were cumulatively changed to OFFROAD parameters until all parameters (except BER) were changed. Changes in BER could not be analyzed in the same way since unlike BAH's emission rates, OFFROAD BERs are not constant for the lifetime of the engine. Thus, the TPD estimate cannot be calculated using the formula given above. Therefore, the final step to this stepwise analysis was done using the OFFROAD model.

To elaborate, OFFROAD models the BER as a function of the initial (zero-hour) emission rate (g/(hp*hr)), deterioration rate (g/(hp*hr)/hr) and cumulative hours. In this way, it can better account for changes in an engine's emission rate with respect to its age and usage. In comparison, BAH's constant BER is an average BER that does not change for the lifetime of the engine. The following formula details how BERs are modeled in OFFROAD. Please note that while BAH has equipment specific BERs, OFFROAD BERs are broken down by engine type and HP groupings.

Equation 7: $\mathbf{BER_{MY} = (ZH + DR * CumHrs_{MY})}$

Where:

$BER_{MY, HP}$ = Engine type and HP group specific BER in (g/(hp*hr)) for an equipment type in a given MY

ZH = Zero Hour emission rate in (g/(hp*hr)) for a specific engine type and HP group

DR = Deterioration rate in (g/(hp*hr)/hr) for a specific engine type and HP group

$CumHrs_{MY}$ = Age_{MY} (yrs) * Activity (hrs/yr)

To accurately reflect this BER change from BAH to OFFROAD requires calculating a TPD estimate while accounting for a BER that deteriorates with time. This requires taking into account the life or attrition as well as a model year distribution of an equipment in a given year. The following methodology used to calculate TPD estimates for BER with deterioration factor is based on the one used in the OFFROAD model.

Equation 8:

$$\mathbf{TPD_{Equip,\,HP} = \Sigma_{MY}\ (Pop_{MY,\,HP} * Activity * Avg\ HP_{HP} * Load * BER_{MY,\,HP}) * CnvFac}$$

Where:
TPD_{Equip} = Ton per day emissions of a pollutant for an equipment
$Pop_{MY,\,HP}$ = Number of units of an equipment for a given model year and HP group
Activity = Usage in (hrs/yr) for the equipment
$Avg\ HP_{HP}$ = Average horsepower (hp) for the equipment in the given HP group
Load = Average load factor
$BER_{MY,\,HP}$ = Engine and HP group specific Base Emission Rate for a pollutant in (g/(hp*hr)) in a given model year
CnvFac = Conversion Factor from (g/yr) to (tons/day)

The final step in the stepwise analysis which accounts for BER changes from BAH to the OFFROAD model is the OFFROAD model TPD output itself. It should be noted that the OFFROAD model calculates TPD emission estimates per equipment on an engine type and HP group specific level. Therefore, the OFFROAD model TPD outputs will not only show the effects of the BER changes but also the differences that come from evaluating emissions at an equipment, engine type and HP specific level.

Reasons for Discrepancies between BAH and OFFROAD:

In comparison to BAH, the OFFROAD model contains a more comprehensive list of equipment from a wider range of equipment categories and includes diesels, CNG/LPG in addition to G2 and G4 engine types. A total of 30.76 TPD of HC+NOx comes from equipment not previously accounted for in BAH

For OFFROAD equipment that could be categorized under BAH L&G or GenUtil category, the TPD differences between OFFROAD and BAH originates from differences in the input parameters (population, activity, average HP, load, life) as well as differences in the basic organization and level of detail of these parameters.

When looking at the contributions of each parameter separately, the TPD increases/decreases corresponds directly to increases/decreases in the averages of parameter inputs. For example, an average population increase from BAH to OFFROAD shows a corresponding increase in TPD.

Evaluating the combined contributions of more than one parameter is not as obvious. With more than one parameter, the interactions between the parameter can amplify or filter the effect one parameter alone may have on the TPD total. G2 GenUtil category shows an example of how increases and decreases in more than one parameter can average out the overall effect from all the parameters. G4 GenUtil category shows the amplifying effect of having an increase in all parameters.

The difference in the OFFROAD model methodology in evaluating TPD emissions on an equipment, engine type and HP group specific level is evident in the TPD increases for equipment under BAH L&G and GenUtil categories.

For equipment classified under BAH's L&G category, BAH had equipment level information from which to calculate the TPD estimates. BAH was the source for equipment level usage, load and population values in OFFROAD for all except average HP where it was not specific enough to the HP groupings that exist in the OFFROAD model so HP group specific data from PSR was used. Similarity between BAH and OFFROAD is reflected in the relatively small TPD increases for each change in parameter. The largest increase is due to the change in BER which will be discussed separately.

Equipment classified under BAH's GenUtil category were not equipment specific in BAH. BAH's TPD estimate was calculated based on an average population, usage, load, average HP and BERs value for the entire category. OFFROAD TPD estimates were based on population, usage, load, average HP and BERs values from PSR at an equipment and HP group level. These changes in parameter as well as level of detail are reflected in the relatively large increases in TPD for equipment under BAH GenUtil category.

For both BAH L&G and GenUtil G4 engines, the increase in TPD from Pop+Act+Load+AvgHP to the OFFROAD output shows the effect of using engine type and HP group specific BER with deterioration factors. For G2s, BER deterioration factors are not currently modeled in OFFROAD so the difference in the BER is from engine type and HP group specific BERs in OFFROAD vs. equipment specific BERs in BAH. Although OFFROAD's HP group specific G2 BERs were derived from BAH's equipment specific BERs, differences in having an equipment specific vs. an engine type and HP group specific BER resulted in an increase in the TPD emissions. These increases can be traced to differences between OFFROAD and BAH's BER for all handheld equipment.

One of the comments received from the workshop was that G2 BERs were not representative of G2 handheld (HH) equipment. The only G2 BERs available was from BAH which was equipment specific but not HP or HH/NH specific. In order to better reflect G2 HH and non-handheld (NH) BERs, we derived new OFFROAD G2 BER from BAH's equipment specific composite BERs. (Note: composite BERs = BAH's residential and commercial BERs that were activity weighted to create a composite G2, equipment specific emission rate as detailed above). BAH's equipment specific composite BERs were recomposited to a G2, HP and HH/NH specific BER for OFFROAD in the following way.

1. Each equipment type in BAH and OFFROAD was classified as HH/NH.

2. For each OFFROAD equipment type, the same corresponding equipment specific BER from BAH was used regardless of HP grouping.

3. Computed equipment and HP group specific activity weighting for each G2 equipment in OFFROAD using equipment and HP specific activity and population.

Equation 9: Act Wt = Pop*AvHP*Load*Activity

Where:
Act Wt = Equipment and HP specific activity weighting in (hp*hr/yr)
Pop = Number of units
AvHP = Average horsepower
Load = Average load factor
Activity = Usage in (hrs/yr)

4. Using HP specific activity, calculated Ann ER (g/yr) for each equipment and HP group.

Equation 10: Ann ER = Act Wt * BER

Where:
Ann ER = Annual Emission rate in (g/yr)
Act Wt = HP group specific activity weighting in (hp*hr/yr)
BER = BAH's composite equipment specific Base Emission Rate in (g/(hp*hr))

5. Subtotaled annual emission rates (g/yr) and activity weights (hp*hr/yr) of all equipments by HH/NH and HP groups.

6. Divided each subtotaled annual emission rate (g/yr) by corresponding activity weight (hp*hr/yr) per HH/NH and HP group to get HH/NH and HP group specific BERs.

Equation 11: $\mathbf{BER_{HH,\,HP} = Ann\ ER_{HH,\,HP} / ActWt_{HH,\,HP}}$
$\mathbf{BER_{NH,\,HP} = Ann\ ER_{NH,\,HP} / ActWt_{NH,\,HP}}$

Where:
$BER_{HH,\,HP}$ = HH, HP specific base emission rate in (g/(hp*hr))
Ann $ER_{HH,\,HP}$ = HH, HP specific annual emission rate in (g/yr)
$ActWt_{HH,\,HP}$ = HH, HP specific activity weighting (hp*hr/yr)

$BER_{NH,\,HP}$ = NH, HP specific base emission rate in (g/(hp*hr))
Ann $ER_{NH,\,HP}$ = NH, HP specific annual emission rate in (g/yr)
$ActWt_{NH,\,HP}$ = NH, HP specific activity weighting (hp*hr/yr)

When assigning BAH BERs to corresponding equipment in OFFROAD, if the equipment in OFFROAD was not accounted for in BAH (ie did not exist in BAH), it was not assigned a BAH BER. These equipment types are not represented in the newly recomposited BERs. Only two G2 equipment types fell under this category. (Other Industrial Equip and Plate Compacters, 2-15hp group, NH). These equipment types display relatively little activity. Therefore, the overall impact is assumed to be minimal. The resulting HH/NH and HP specific emission rates still have no deterioration rates, but are not equipment specific as in BAH. Hence, the difference in the TPD total due to BER depends on how BAH's equipment specific BERs compare to the OFFROAD HP specific BERs.

Table 1
BAH to OFFROAD
Stepwise Difference Analysis

Data

BAH Category	Engine Type	Parameters	HC (tpd)	CO (tpd)	NOx (tpd)	PM (tpd)	HC (% diff)	CO (% diff)	NOx (% diff)	PM (% diff)
BAH L&G	G2**	None (BAH)	50.773	158.854	0.217	1.047	0.000	0.000	0.000	0.000
		Activity	51.189	160.204	0.220	1.056	0.008	0.009	0.011	0.009
		AvHP	55.873	174.713	0.242	1.169	0.100	0.100	0.116	0.117
		Load	51.259	160.201	0.219	1.061	0.010	0.008	0.008	0.014
		Pop	51.094	159.604	0.218	1.059	0.006	0.005	0.002	0.011
		Pop+Act	51.510	160.955	0.220	1.068	0.015	0.013	0.013	0.020
		Pop+Act+Load	52.394	163.238	0.222	1.097	0.032	0.028	0.024	0.048
		Pop+Act+Load+AvgHP	57.488	179.194	0.248	1.217	0.132	0.128	0.142	0.163
		*All (OFFROAD output)	64.736	199.883	0.276	1.444	0.275	0.258	0.269	0.380
	G4	None (BAH)	14.962	247.474	1.294	0.271	0.000	0.000	0.000	0.000
		Activity	15.071	251.139	1.315	0.276	0.007	0.015	0.016	0.019
		AvHP	15.907	262.266	1.367	0.285	0.063	0.060	0.056	0.052
		Load	15.204	255.592	1.340	0.282	0.016	0.033	0.035	0.041
		Pop	14.850	243.713	1.273	0.266	-0.008	-0.015	-0.016	-0.019
		Pop+Act	14.898	245.329	1.282	0.268	-0.004	-0.009	-0.009	-0.011
		Pop+Act+Load	15.063	250.866	1.313	0.275	0.007	0.014	0.015	0.017
		Pop+Act+Load+AvgHP	16.004	265.521	1.385	0.289	0.070	0.073	0.071	0.069
		*All (OFFROAD output)	19.093	374.336	2.107	0.458	0.276	0.513	0.628	0.692
GenUtil	G2**	None (BAH)	2.586	6.042	0.004	0.096	0.000	0.000	0.000	0.000
		Activity	6.316	14.757	0.009	0.234	1.442	1.442	1.442	1.442
		AvHP	0.864	2.019	0.001	0.032	-0.666	-0.666	-0.666	-0.666
		Load	3.405	7.955	0.005	0.126	0.317	0.317	0.317	0.317
		Pop	4.921	11.497	0.007	0.182	0.903	0.903	0.903	0.903
		Pop+Act	12.018	28.081	0.017	0.445	3.648	3.648	3.648	3.648
		Pop+Act+Load	15.824	36.974	0.022	0.586	5.119	5.119	5.119	5.119
		Pop+Act+Load+AvgHP	5.288	12.355	0.007	0.196	1.045	1.045	1.045	1.045
		*All (OFFROAD output)	5.498	13.011	0.008	0.201	1.126	1.153	1.308	1.096
	G4	None (BAH)	2.305	83.687	0.477	0.084	0.000	0.000	0.000	0.000
		Activity	4.224	153.330	0.874	0.154	0.832	0.832	0.832	0.832
		AvHP	2.843	103.197	0.588	0.104	0.233	0.233	0.233	0.233
		Load	3.057	110.984	0.633	0.111	0.326	0.326	0.326	0.326
		Pop	3.376	122.571	0.699	0.123	0.465	0.465	0.465	0.465
		Pop+Act	6.186	224.571	1.280	0.225	1.683	1.683	1.683	1.683
		Pop+Act+Load	8.204	297.821	1.698	0.299	2.559	2.559	2.559	2.559
		Pop+Act+Load+AvgHP	10.117	367.252	2.094	0.369	3.388	3.388	3.388	3.388
		*All (OFFROAD output)	20.107	496.937	3.892	0.388	7.722	4.938	7.157	3.614
Not in BAH	G2**	*All (OFFROAD output)	0.162	0.510	0.001	0.003	0.000	0.000	0.000	0.000
	G4	*All (OFFROAD output)	11.244	292.067	2.330	0.211	0.000	0.000	0.000	0.000
	C4	*All (OFFROAD output)	0.056	1.862	0.016	0.001	0.000	0.000	0.000	0.000
	D	*All (OFFROAD output)	3.062	8.827	13.900	1.478	0.000	0.000	0.000	0.000

* 1990 Cal Year OFFROAD model output includes OFFROAD specific
Pop + Activity + Load + AvgHP + BERs (w/DRs)

** This analysis was performed before including some additional comments from
manufacturers as described in the report.

Appendix B

Detailed Inventory Listing (Data and Emission Factors)

OFFROAD Model Input Factors

								(yrs)	*(hp)*		*(lb/hp-hr)*	*(hrs/yr)*
Category	Equip Des	Eng Type	HH/NHH	HP	(P/N)	1990 Pop	2010 Pop	Life	AvHP	Load	BSFC	Activity
Agriculture	2-Wheel Tractors	G4	NHH	5	P	953	1168	2	4	0.62	1.09	160
				15	P	1109	1359	3	8	0.62	0.9	332
				25	P	30	36	3	16	0.62	0.8	332
	Agricultural Mowers	G4	NHH	15	P	990	1213	8	8	0.48	0.9	180
				25	P	810	992	8	18	0.48	0.8	180
	Agricultural Tractors	D	NHH	15	P	14764	23587	3	12	0.7	0.65	532
				25	P	18206	29086	6	23	0.7	0.53	532
	Hydro Power Units	D	NHH	15	P	57	91	3	10	0.48	0.65	814
				25	P	172	274	6	19	0.48	0.53	814
		G4	NHH	5	P	226	277	2	5	0.56	1.09	175
				15	P	452	554	2	8	0.56	0.9	464
				25	P	172	210	2	17	0.56	0.8	464
	Other Agricultural Equipment	D	NHH	15	P	208	332	5	12	0.51	0.65	446
				25	P	578	923	11	22	0.51	0.53	446
		G4	NHH	5	P	158	193	2	4	0.55	1.09	145
				15	P	138	169	9	10	0.55	0.9	145
				25	P	35	42	9	25	0.55	0.8	145
	Sprayers	D	NHH	25	P	304	485	16	19	0.5	0.53	110
		G4	NHH	5	P	3756	4604	4	4	0.5	1.09	98
				15	P	1169	1432	15	7	0.5	0.9	98
				25	P	3024	3706	15	17	0.5	0.8	98
	Tillers >5 HP	D	NHH	15	N	7	11	6	7	0.78	0.65	263
		G4	NHH	15	N	127845	156715	14	7	0.71	0.9	71
Airport Grnd Support	Cart	G4	NHH	15	N	23	26	5	12	0.5	0.9	150
	Lav Cart	G4	NHH	15	N	3	6	5	12	0.5	0.9	150
Construction	Asphalt Pavers	D	NHH	25	P	14	16	10	24	0.62	0.53	396
		G4	NHH	15	P	66	77	2	9	0.66	0.9	396
				25	P	113	133	2	22	0.66	0.8	396
	Bore/Drill Rigs	D	NHH	15	P	9	10	3	11	0.75	0.65	541
				25	P	28	32	6	17	0.75	0.53	541
		G4	NHH	15	P	31	36	7	10	0.79	0.9	124
				25	P	153	180	7	18	0.79	0.8	124
	Cement and Mortar Mixers	D	NHH	15	P	488	570	7	9	0.56	0.65	300
				25	P	44	51	14	25	0.56	0.53	300
		G4	NHH	5	P	10226	12047	3	5	0.59	1.09	92
				15	P	17327	20412	13	8	0.59	0.9	92
				25	P	73	86	13	25	0.59	0.8	92
	Concrete/Industrial Saws	D	NHH	25	P	4	4	5	18	0.73	0.53	592
		G4	NHH	5	P	563	663	2	4	0.78	1.09	130
				15	P	2533	2984	3	9	0.78	0.9	310
				25	P	792	933	3	17	0.78	0.8	310
	Crushing/Proc. Equipment	G4	NHH	15	P	28	32	3	9	0.85	0.9	289
				25	P	18	21	3	16	0.85	0.8	289
	Dumpers/Tenders	D	NHH	25	P	23	26	9	16	0.38	0.53	662
		G4	NHH	5	P	522	614	3	4	0.41	1.09	149
				15	P	1113	1311	12	9	0.41	0.9	149
				25	P	206	242	12	19	0.41	0.8	149
	Excavators	D	NHH	25	P	27	31	4	23	0.57	0.53	893
	Other Construction Equipment	D	NHH	15	P	316	369	3	13	0.62	0.65	612
				25	P	53	61	6	17	0.62	0.53	612
	Paving Equipment	D	NHH	25	P	174	203	6	19	0.53	0.53	709

		G4	NHH	5	P	7196	8477	2	4	0.59	1.09	170
				15	P	12174	14342	6	10	0.59	0.9	200
				25	P	271	319	6	22	0.59	0.8	200
	Plate Compactors	D	NHH	15	P	313	365	4	8	0.43	0.65	600
		G2	NHH	15	P	259	305	3	4	0.55	1.3	206
		G4	NHH	5	P	5142	6057	2	4	0.55	1.09	180
				15	P	5454	6425	6	8	0.55	0.9	206
	Rollers	D	NHH	15	P	578	675	3	9	0.56	0.65	745
				25	P	242	282	6	19	0.56	0.53	745
		G4	NHH	5	P	573	675	3	5	0.62	1.09	83
				15	P	927	1092	3	9	0.62	0.9	310
				25	P	626	737	3	19	0.62	0.8	310
	Rubber Tired Loaders	D	NHH	25	P	13	15	5	25	0.54	0.53	875
	Signal Boards	D	NHH	15	P	2688	3140	2	6	0.82	0.65	750
		G4	NHH	5	P	16	18	2	5	0.76	1.09	130
				15	P	116	136	3	8	0.76	0.9	284
	Skid Steer Loaders	D	NHH	25	P	1676	1957	5	20	0.55	0.53	843
		G4	NHH	15	P	55	64	4	14	0.58	0.9	319
				25	P	3656	4307	4	19	0.58	0.8	319
	Surfacing Equipment	G4	NHH	5	P	1321	1556	2	5	0.49	1.09	200
				15	P	3926	4625	3	8	0.49	0.9	503
				25	P	54	63	3	19	0.49	0.8	503
	Tampers/Rammers	G2	NHH	15	P	3021	3558	4	4	0.55	1.3	182
		G4	NHH	15	P	140	164	7	9	0.55	0.9	182
	Tractors/Loaders/Backhoes	D	NHH	25	P	177	206	8	23	0.55	0.53	570
	Trenchers	D	NHH	15	P	67	78	2	9	0.75	0.65	640
				25	P	70	81	5	35	0.75	0.53	640
		G4	NHH	15	P	1074	1265	2	10	0.66	0.9	434
				25	P	832	980	2	21	0.66	0.8	434
Lawn & Garden	Chainsaws <=5 HP	G2	HH	2	N	197560	264943	5	1.03	0.5	1.3	82.6
				15	N	139171	186639	5	2.49	0.5	1.3	82.6
				15	P	173220	232301	5	2.49	0.5	1.3	82.6
	Chippers/Stump Grinders	D	NHH	25	P	8	10	5	22	0.73	0.5	465
		G4	NHH	15	P	267	358	5	11	0.78	0.9	465
				25	P	1511	2026	5	18	0.78	0.8	465
	Commercial Turf Equipment	D	NHH	15	N	415	556	4	14	0.55	0.7	1068
				25	N	7807	10469	4	21	0.55	0.5	1068
		G2	NHH	15	N	795	1066	4	9	0.5	1.3	800
				25	N	392	525	4	19	0.5	1.3	800
		G4	NHH	15	N	7157	9598	4	11	0.5	0.9	800
				25	N	3525	4727	4	19	0.5	0.8	800
	Front Mowers	G4	NHH	15	N	40967	54939	7	13	0.42	0.9	49.6
				25	N	32085	43028	7	17	0.42	0.8	49.6
	Lawn & Garden Tractors	D	NHH	15	N	16500	22127	7	13	0.57	0.7	544
				25	N	12910	17313	7	20	0.57	0.5	544
		G4	NHH	15	N	28114	37703	7	11	0.6	0.9	59.7
				25	N	11088	14869	7	17	0.6	0.8	59.7
	Lawn Mowers	G2	NHH	15	N	159157	213441	7	4	0.36	1.3	55.3
		G4	NHH	5	N	1989369	2667896	7	4	0.36	1.1	35.9
	Leaf Blowers/Vacuums	D	NHH	15	N	7	9	6	6	0.4	0.7	120
		G2	HH	2	N	345564	463428	5	1	0.5	1.3	85.5
		G4	NHH	5	N	3638	4878	6	2	0.36	1.1	57.87
	Other Lawn & Garden Equipmen	D	NHH	15	N	6	8	5	15	0.65	0.7	433
				25	N	1	1	5	20	0.65	0.5	433
		G2	HH	2	N	2876	3856	4	1	0.58	1.3	61
				15	N	1252	1679	4	5	0.58	1.3	61
		G4	NHH	5	N	53807	72159	5	4	0.58	1.1	61

				15	N	23897	32047	5	8	0.58	0.9	61
				25	N	508	681	5	17	0.58	0.8	61
	Rear Engine Riding Mowers	G4	NHH	15	N	24268	32545	7	9	0.38	0.9	46.5
				25	N	109	146	7	17	0.38	0.8	46.5
	Shredders <=5 HP	G2	NHH	15	P	2669	3579	4	6	0.8	1.3	126.3
		G4	NHH	5	P	6943	9311	5	4	0.8	1.1	39.06
	Snowblowers	G2	HH	15	N	2107	3177	5	6	0.35	1.3	16.5
				25	N	3	4	5	16	0.35	1.3	16.5
		G4	NHH	5	N	22795	34381	5	4	0.35	1.1	16.5
				15	N	17247	26013	5	9	0.35	0.9	16.5
				25	N	50	75	5	16	0.35	0.8	16.5
	Tillers	G4	NHH	5	N	119385	160104	7	4	0.4	1.1	37.3
	Trimmers/Edgers/Brush Cutter	G2	HH	2	N	684740	918289	5	0.9	0.5	1.3	46
		G4	NHH	5	N	52979	71048	6	1	0.36	1.1	60
	Wood Splitters	G4	NHH	5	N	62209	83427	5	5	0.69	1.1	76
Light Duty Commercial	Air Compressors	D	NHH	15	P	50	57	16	12	0.48	0.7	815
				25	P	103	118	16	24	0.48	0.5	815
		G4	NHH	5	P	6012	6952	1	5	0.56	1.1	484
				15	P	3043	3518	3	7	0.56	0.9	484
				25	P	410	474	4	17	0.56	0.8	484
	Generator Sets	D	NHH	15	N	4908	5627	16	11	0.74	0.7	338
				25	N	3590	4116	16	19	0.74	0.5	338
		G2	NHH	2	N	3574	4132	16	1	0.68	1.3	11.49
				15	N	36	41	12	9	0.68	1.3	115
		G4	NHH	5	N	46918	54255	16	4	0.68	1.1	11.49
				15	N	128874	149028	12	9	0.68	0.9	115
				25	N	69241	80069	12	19	0.68	0.8	115
	Pressure Washers	D	NHH	15	N	228	261	16	13	0.3	0.7	145
				25	N	53	60	16	19	0.3	0.5	145
		G4	NHH	5	N	12603	14573	12	5	0.85	1.1	12.25
				15	N	11243	13001	12	7	0.85	0.9	115
				25	N	2111	2441	11	18	0.85	0.8	115
	Pumps	D	NHH	15	P	3686	4226	16	8	0.74	0.7	403
				25	P	1101	1262	16	21	0.74	0.5	403
		G2	NHH	2	N	14203	16424	10	1	0.69	1.3	22.64
				15	P	3830	4428	8	8	0.69	1.3	221
				25	P	46	53	6	17	0.69	1.3	221
		G4	NHH	5	P	16642	19244	10	3	0.69	1.1	22.64
				15	P	18034	20854	8	8	0.69	0.9	221
				25	P	4619	5341	6	17	0.69	0.8	221
	Welders	D	NHH	15	P	1667	1911	16	11	0.45	0.7	643
				25	P	1467	1682	16	20	0.45	0.5	643
		G4	NHH	15	P	6584	7613	11	11	0.51	0.9	208
				25	P	23800	27522	9	17	0.51	0.8	208
Light Duty Industrial	Aerial Lifts	C4	NHH	15	P	17	21	2	13	0.46	0.55	375
				25	P	715	912	4	19	0.46	0.55	375
		D	NHH	15	P	93	103	6	15	0.46	0.65	399
				25	P	152	168	13	19	0.46	0.53	399
		G4	NHH	15	P	17	19	2	13	0.46	0.9	375
				25	P	715	799	4	19	0.46	0.8	375
	Forklifts	C4	NHH	25	N	7	8	2	23	0.3	0.55	1250
		G4	NHH	25	N	17	19	2	23	0.3	0.8	900
	Other General Industrial Equ	D	NHH	15	N	86	95	2	10	0.51	0.65	1071
				25	N	86	95	4	24	0.51	0.53	1071
		G2	NHH	15	N	87	97	2	8	0.54	1.3	375

		G4	NHH	15	N	964	1077	2	8	0.54	0.9	375
				25	N	316	353	3	18	0.54	0.8	430
	Sweepers/Scrubbers	D	NHH	15	N	55	61	2	14	0.68	0.65	650
				25	N	55	61	5	23	0.68	0.53	650
		G4	NHH	15	N	486	543	2	8	0.71	0.9	270
				25	N	475	531	3	18	0.71	0.8	270
Logging	Chainsaws >5 HP	G2	HH	15	P	8097	10492	2	8	0.92	1.3	206
	Shredders >5 HP	G4	NHH	15	P	12704	16462	3	8	0.8	0.9	242
Trans. Refrig	Transport Refrigeration Unit	D	NHH	25	N	1305	1640	6	17	0.5	0.53	750
		G4	NHH	15	N	4367	5526	2	12	0.5	0.9	750

HP	Horsepower	HH	Handheld
P	Preempted	NHH	Non-handheld
N	Nonpreempted		
Pop	Equipment Population		
BSFC	Break Specific Fuel Consumption		
D	Diesel		
G2	Gasoline - 2 stroke		
G4	Gasoline - 4 stroke		

Note: In this attachment there are G2, NHH equipment shown under G2 category for calendar year 2010. For emission calculations purposes, it was assumed that there will not be any G2, NHH equipment in 2010. Population and activity of G2, NHH equipment shown in 2010 are added to G4 population.

Emission Factors for Small Off-road Engine (Non-preempted)

				HC		CO		NOx		PM	
Fuel	stds	MY	hp	ZH	DR	ZH	DR	ZH	DR	ZH	DR
G2	unctrl - HH	pre-95	0-2	226.470	0.0000	740.360	0.0000	0.960	0.0000	3.600	0.0000
	unctrl - NHH	pre-95		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1995-99		141.824	0.0000	297.930	0.0000	0.904	0.0000	3.600	0.0000
	tier2	2000+		38.970	0.3430	64.550	0.7780	0.900	0.0000	0.250	0.0112
	unctrl - HH	pre-95	2-15	159.570	0.0000	522.000	0.0000	0.847	0.0000	3.620	0.0000
	unctrl - NHH	pre-95		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1995-99		132.841	0.0000	282.350	0.0000	0.767	0.0000	4.289	0.0000
	tier2	2000+		36.900	0.1920	61.180	0.4420	0.770	0.0000	0.250	0.0081
	unctrl - HH	pre-95	15-25	208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	unctrl - NHH	pre-95		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1995-99		88.561	0.0000	141.175	0.0000	0.767	0.0000	4.289	0.0000
	tier2	2000+		36.900	0.1030	61.180	0.1600	0.770	0.0000	0.250	0.0081
G4	unctrl	pre-95	0-5	26.435	0.0948	504.250	0.5196	2.115	0.0002	0.741	0.0026
	tier1	1995-96		7.279	0.0565	272.560	-0.0670	2.322	0.0031	0.741	0.0026
		1997-98		7.279	0.0565	317.986	-0.0670	2.322	0.0031	0.741	0.0026
	tier2	1999+		2.430	0.0565	90.850	-0.0670	0.770	0.0031	0.741	0.0026
	unctrl	pre-95	5-15	7.460	0.0178	393.100	0.0337	3.480	0.0013	0.138	0.0002
	tier1	1995-96		4.557	0.0207	234.543	0.0895	2.838	0.0000	0.138	0.0002
		1997-98		4.557	0.0207	273.634	0.0895	2.838	0.0000	0.138	0.0002
	tier2	1999+		1.970	0.0207	78.180	0.0895	1.230	0.0000	0.138	0.0002
	unctrl	pre-95	15-25	7.460	0.0141	393.100	0.0276	3.480	0.0011	0.138	0.0002
	tier1	1995-96		4.421	0.0166	243.166	0.0345	2.322	0.0000	0.138	0.0002
		1997-98		4.421	0.0166	283.693	0.0345	2.322	0.0000	0.138	0.0002
	tier2	1999+		2.100	0.0166	81.060	0.0345	1.100	0.0000	0.138	0.0002
D	unctrl	pre-95	0-15	1.500	0.0000	5.000	0.0000	10.000	0.0000	1.000	0.0000
	tier1	1995-96		1.306	0.0000	1.908	0.0000	3.460	0.0000	0.351	0.0000
		1997-98		1.306	0.0000	2.226	0.0000	3.460	0.0000	0.351	0.0000
	tier2	1999+		0.420	0.0000	0.640	0.0000	1.100	0.0000	0.097	0.0000
	unctrl	pre-95	15-25	1.844	0.0000	5.000	0.0000	6.920	0.0000	0.764	0.0000
	tier1	1995-96		1.632	0.0000	1.419	0.0000	3.888	0.0000	0.417	0.0000
		1997-98		1.632	0.0000	1.655	0.0000	3.888	0.0000	0.417	0.0000
	tier2	1999+		0.520	0.0000	0.470	0.0000	1.240	0.0000	0.116	0.0000
C4	unctrl	pre-95	0-5	4.245	0.0042	248.400	0.0144	1.990	0.0004	0.490	0.0001
	tier1	1995-96		4.245	0.0042	248.400	0.0144	1.990	0.0004	0.490	0.0001
		1997-98		4.245	0.0042	248.400	0.0144	1.990	0.0004	0.490	0.0001
	tier2	1999+		2.180	0.0042	100.000	0.0144	1.020	0.0004	0.250	0.0001
	unctrl	pre-95	5-15	3.960	0.0042	240.000	0.0144	1.770	0.0004	0.092	0.0001
	tier1	1995-96		3.960	0.0042	240.000	0.0144	1.770	0.0004	0.092	0.0001
		1997-98		3.960	0.0042	240.000	0.0144	1.770	0.0004	0.092	0.0001
	tier2	1999+		2.210	0.0042	100.000	0.0144	0.990	0.0004	0.092	0.0001
	unctrl	pre-95	15-25	3.960	0.0041	240.000	0.0142	1.770	0.0004	0.092	0.0001
	tier1	1995-96		3.960	0.0041	240.000	0.0142	1.770	0.0004	0.092	0.0001
		1997-98		3.960	0.0041	240.000	0.0142	1.770	0.0004	0.092	0.0001
	tier2	1999+		2.210	0.0041	100.000	0.0142	0.990	0.0004	0.092	0.0001

ZH g/bhp-hr

DR g/bhp-hr^2

Emission Factors for Small Off-road Engine (Preempted)

				HC		CO		NOx		PM	
Fuel	stds	MY	hp	ZH	DR	ZH	DR	ZH	DR	ZH	DR
G2	unctrl - HH	pre-97	0-2	226.470	0.0000	740.360	0.0000	0.960	0.0000	3.600	0.0000
	unctrl - NHH	pre-97		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1997+		141.824	0.0000	297.930	0.0000	0.904	0.0000	3.600	0.0000
	unctrl - HH	pre-97	2-15	159.570	0.0000	522.000	0.0000	0.847	0.0000	3.620	0.0000
	unctrl - NHH	pre-97		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1997+		132.841	0.0000	282.350	0.0000	0.767	0.0000	4.289	0.0000
	unctrl - HH	pre-97	15-25	208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	unctrl - NHH	pre-97		208.000	0.0000	486.000	0.0000	0.290	0.0000	7.700	0.0000
	tier1	1997+		88.561	0.0000	211.760	0.0000	0.767	0.0000	4.289	0.0000
G4	unctrl	pre-97	0-5	26.435	0.0948	504.250	0.5196	2.115	0.0002	0.741	0.0026
	tier1	1997+		7.279	0.0565	351.600	-0.0670	2.322	0.0031	0.741	0.0026
	unctrl	pre-97	5-15	7.460	0.0178	393.100	0.0337	3.480	0.0013	0.138	0.0002
	tier1	1997+		4.557	0.0207	302.560	0.0895	2.838	0.0000	0.138	0.0002
	unctrl	pre-97	15-25	7.460	0.0141	393.100	0.0276	3.480	0.0011	0.138	0.0002
	tier1	1997+		4.421	0.0166	313.680	0.0345	2.322	0.0000	0.138	0.0002
D	unctrl	pre-97	0-15	1.500	0.0000	5.000	0.0000	10.000	0.0000	1.000	0.0000
	tier1	1997+		1.306	0.0000	2.460	0.0000	3.460	0.0000	0.351	0.0000
	unctrl	pre-97	15-25	1.844	0.0000	5.000	0.0000	6.920	0.0000	0.764	0.0000
	tier1	1997+		1.632	0.0000	1.830	0.0000	3.888	0.0000	0.417	0.0000
C4	unctrl	pre-97	0-5	4.245	0.0042	248.400	0.0144	1.990	0.0004	0.490	0.0001
	tier1	1997+		4.245	0.0042	248.400	0.0144	1.990	0.0004	0.490	0.0001
	unctrl	pre-97	5-15	3.960	0.0042	240.000	0.0144	1.770	0.0004	0.092	0.0001
	tier1	1997+		3.960	0.0042	240.000	0.0144	1.770	0.0004	0.092	0.0001
	unctrl	pre-97	15-25	3.960	0.0041	240.000	0.0142	1.770	0.0004	0.092	0.0001
	tier1	1997+		3.960	0.0041	240.000	0.0142	1.770	0.0004	0.092	0.0001

ZH g/bhp-hr

DR g/bhp-hr^2